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Quarterly Progress Report No. 2

ACCELERATION FACTOR DETERMINATION

FOR METAL FILM RESISTORS

Prepared under Contract No. NAS8-11076

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ELECTRA MANUFACTURING COMPANY

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Quarterly Progress Report No. 2
March 15, 1964-June 15, 1964

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Prepared under Contract No. NAS8-11076 by
ELECTRA MANUFACTURING COMPANY
Independence, Kansas

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Huntsville, Alabama

ABSTRACT

15380

This report covers the work performed during the second quarter of the contract period of performance.

Analysis of variance of the Phase I Screen Test data and the Phase I Temperature-Power Stress Tests was undertaken employing the method of "significant differences".

Upon completion of the Phase III Screen Tests the matrix conditions for the Phase III Life Test were determined and the Phase III Life Test was initiated.

Forty (40) resistors were damaged by an accidental overload and were replaced from the standby units.

Author

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1.0 INTRODUCTION

The purpose of this contract is to develop and conduct a matrix test for metal film resistors employing temperature, power dissipation, and vibration as the stress. The test results will be evaluated and valid acceleration factors established for the different combinations and levels of stress.

An acceleration factor for metal film resistors is to be established by employing various stress matrix tests and a mathematical formula based on the Weibull Distribution. Upon completion of the initial tests, a matrix of useful individual stresses or combinations thereof will be determined and longer term tests will be completed through the range from low to high stress conditions to generate the necessary plots for a verified acceleration factor.

All failures are to be analyzed to determine the modes of failure. The condition and cause is to be determined for each mode of failure, and from the distribution of failures versus stress levels it will be established whether each mode is a function of design, process, or materials. Appropriate stress screening techniques capable of detecting the known modes of failure are to be established.

The Second Quarterly Report continues with the analysis of data from the Phase I Matrix and the testing of components in the Phase III Matrix.

2.0 FACTUAL DATA

2.1 Effects of Screen Testing on Life Test Results

A comparison of data was made to test for significant differences between screened and unscreened units during the various stress conditions of the 1000-hr. Life Test. Data for Manufacturing Types A, B & C were used collectively for this first comparison. Results are shown in Table I for both 100 ohm and 39.2K ohm units. Table values for F were taken from Table A-7a.F Distribution, upper 5% points ($F_{.95}$) degrees of freedom for numerator, Page 388 of "Introduction to Statistical Analysis", Dixon & Massey, McGraw-Hill, 1957. Significant differences are seen between results of the screened and unscreened groups in thirteen of the thirty-two cases and in three cases the severity of the test conditions made the data uncomparable. The most promising results as far as indicating differences between screened and unscreened units appear in the 25°C, 70°C and 125°C temperature groups which were loaded from 1 X rated power to 5 X rated power. The 150°C and 10 X rated power groups showed little or no significant difference between the screened and unscreened groups. Probably the differences indicated in the lower stress conditions were masked by the increased severity of the higher stress conditions.

2.2 Comparison of All Phase I Tests for Each Type

Variance of data was compared for each Manufacturing Type (I.e., A, B and C) for all tests performed in Phase I. Overstress Load (S.T.O.L.) was eliminated in this comparison since the

100 OHM

Rated Power	X 1	X $2\frac{1}{2}$	X 5	X 10
25°C:				
Screened Variance	.0001	.00083	.0025	.0235
Unscreened Variance	.0005	.00058	.0008	.0073
F - Ratio	5.000	1.431	3.125	3.219
Table Value $F_{.95}$	(30, 30) = 1.84	(30, 30) = 1.84	(40, 40) = 1.69	(20, 20) = 2.12
70°C:				
Screened Variance	.0009	.0007	.0019	.0486
Unscreened Variance	.0013	.0006	.0074	.0926
F - Ratio	1.44	1.16	3.89	1.91
Table Value $F_{.95}$	(60, 60) = 1.56	(60, 60) = 1.56	(30, 24) = 1.94	(10, 10) = 2.98
125°C:				
Screened Variance	.000239	.0189	.0008	2371.62
Unscreened Variance	.001214	.0041	.00073	3128.476
F - Ratio	5.079	4.61	1.095	1.319
Table Value $F_{.95}$	(40, 40) = 1.69	(30, 30) = 1.80	(10, 10) = 2.98	(15, 15) = 2.62
150°C:				
Screened Variance	.3679	8.5544	175.6472	2668.48
Unscreened Variance	.5203	7.6833	53.2264	2084.84
F - Ratio	1.414	1.113	3.30	1.279
Table Value $F_{.95}$	(60, 60) = 1.56	2.40	2.40	2.40

39.2K

Rated Power	X 1	X $2\frac{1}{2}$	X 5	X 10
25°C:				
Screened Variance	.000406	.001631	.37506	.00327
Unscreened Variance	.000231	.004924	.03848	.00658
F - Ratio	1.758	3.019	9.748	2.012
Table Value $F_{.95}$	(30, 30) = 1.84	(30, 30) = 1.84	(40, 40) = 1.69	(10, 10) = 2.98
70°C:				N = 15
Screened Variance	.001877	.0151	.0540	9 Unstable
Unscreened Variance	.000634	.0006	.0123	6 Greater than 20, 15
F - Ratio	2.961	25.16	4.39	
Table Value $F_{.95}$	(40, 40) = 1.69	(40, 40) = 1.69	(30, 30) = 1.80	
125°C:				N = 15
Screened Variance	.00117	.08374	3.9584	7 Unstable
Unscreened Variance	.00537	.10245	2.7995	9 Unstable
F - Ratio	4.59	1.223	1.4139	
Table Value $F_{.95}$	(40, 40) = 1.69	1.84	(15, 15) = 2.40	
150°C:				N = 15
Screened Variance	.02564	1.1268	11.80351	9 Unstable
Unscreened Variance	.04223	2.7271	15.170	10 Unstable
F - Ratio	1.647	2.42	1.285	
Table Value $F_{.95}$	(40, 40) = 1.69	(15, 15) = 2.40	(9, 11) = 2.90	

TABLE I

100 OHM, 1 X RATED

		A	B	C
Temp. Cycle	ΣX =	2.30	1.49	.85
	ΣX^2 =	.1307	.0641	.0223
Burn-In	ΣX =	.53	-1.38	-.56
	ΣX^2 =	.0109	.2276	.0250
Initial Noise	ΣX =	100.8	214.20	65.3
	ΣX^2 =	4939.66	1256.22	105.71
Load Life	ΣX =	-2.00	9.84	2.88
	ΣX^2 =	.1181	14.269	.1768
F - Ratio		2.048	98.38	143.81
Table Value: $F_{.95}$ = 2.60				

39.2K, 1 X RATED

		A	B	C
Temp. Cycle	ΣX =	.96	3.85	1.16
	ΣX^2 =	.1898	.2818	.0318
Burn-In	ΣX =	-.86	-4.07	-1.66
	ΣX^2 =	.2149	.5921	.1133
Initial Noise	ΣX =	2216.2	15.0	4902.7
	ΣX^2 =	11810.76	23.56	11121.78
Load Life	ΣX =	.03	1.28	1.86
	ΣX^2 =	.0414	1.2886	1.5058
F - Ratio		551.2	12.043	55.40
Table Value: $F_{.95}(3, 60)$ = 2.76				

TABLE II

100 OHM, $2\frac{1}{2}$ X RATED

		A	B	C
Temp. Cycle	$\Sigma X =$	1.48	.80	.55
	$\Sigma X^2 =$	.0808	.0395	.0112
Burn-In	$\Sigma X =$	.15	-.259	-.41
	$\Sigma X^2 =$	.0026	.2309	.0075
Initial Noise	$\Sigma X =$	58.90	153.0	47.0
	$\Sigma X^2 =$	634.36	1301.96	73.58
Load Life	$\Sigma X =$	3.07	19.23	4.15
	$\Sigma X^2 =$	.6055	156.54	.8763
F - Ratio		6.29	20.186	108.42
Table Value: $F_{.95}$ (2, 40) = 2.84				

39.2K, $2\frac{1}{2}$ X RATED

		A	B	C
Temp. Cycle	$\Sigma X =$	1.10	2.45	.85
	$\Sigma X^2 =$	.0501	1.2415	.0265
Burn-In	$\Sigma X =$	-1.02	-1.67	-1.54
	$\Sigma X^2 =$	.1098	1.4925	.0670
Initial Noise	$\Sigma X =$	236.8	236.8	463.6
	$\Sigma X^2 =$	4027.52	4027.52	6935.12
Load Life	$\Sigma X =$	-1.03	16.08	4.85
	$\Sigma X^2 =$	5790.35	3155.2	760.25
F - Ratio		.5759	9.059	89.73
Table Value: $F_{.95}$ (3, 40) = 2.84				

TABLE III

100 OHM, 5 X RATED

		A	B	C
Temp. Cycle	ΣX =	1.38	.59	.72
	ΣX^2 =	.0622	.0285	.0248
Burn-In	ΣX =	.04	-1.52	-.30
	ΣX^2 =	.0024	.0845	.0116
Initial Noise	ΣX =	24.4	113.4	39.9
	ΣX^2 =	31.98	504.28	63.31
Load Life	ΣX =	-.13	176.46	1.70
	ΣX^2 =	.1619	4298.4766	1.2128
F - Ratio		36.99	8.449	78.79
Table Value: $F_{.95}(3, 40) = 2.84$				

39.2K, 5 X RATED

		A	B	C
Temp. Cycle	ΣX =	3.53	2.34	1.00
	ΣX^2 =	6.4983	.1696	.0404
Burn-In	ΣX =	-.47	-1.77	-.13
	ΣX^2 =	.4239	.4937	.8118
Initial Noise	ΣX =	90.8	42.0	372.6
	ΣX^2 =	2322.56	104.36	5401.80
Load Life	ΣX =	7.29	83.74	20.99
	ΣX^2 =	17.4031	426.8008	48.3980
F - Ratio		3.532	22.123	88.317
Table Value: $F_{.95}(3, 40) = 2.84$				

TABLE IV

100 OHM, 10 X RATED

		A	B	C
Temp. Cycle	ΣX =	1.05	.62	.43
	ΣX^2 =	.0619	.0208	.0115
Burn-In	ΣX =	.02	1.0	.27
	ΣX^2 =	.0026	.0606	.0443
Initial Noise	ΣX =	22.3	83.8	26.2
	ΣX^2 =	55.61	359.68	37.08
Load Life	ΣX =	12.87	1288.95	61.54
	ΣX^2 =	23.2905	180753.48	324.7678
F - Ratio		3.199	13.387	16.985
Table Value: $F_{.95}(3, 25) = 2.99$				

39.2K, 10 X RATED

		A	B	C
Temp. Cycle	ΣX =	.52	1.88	
	ΣX^2 =	.0169	.1624	
Burn-In	ΣX =	.50	-.34	
	ΣX^2 =	.0552	.6416	
Initial Noise	ΣX =	58.4	71.4	
	ΣX^2 =	442.68	3413.72	
Load Life	ΣX =	53.82	14 Resistors Unstable	16 Resistors Unstable
	ΣX^2 =	267.9231		
F - Ratio		16.681		
Table Value: $F_{.95}(3, 25) = 2.99$				

TABLE V

SUMMARY
100 OHM

	Temp. Cycle Load Life	Burn-In Load Life	Initial Noise Load Life
F - Ratio			
1 X Rated			
Group A	1.02	7.55	108977.8
Group B	506.38	59.69	34.995
Group C	2.83	1.35	1084.93
Table Value: $F_{.95}$ (1, 60) = 4.00			
$2\frac{1}{2}$ X Rated			
Group A	14.22	182.40	1480.5
Group B	6263.33	642.639	4.866
Group C	124.25	134.48	41.18
Table Value: $F_{.95}$ (1, 40) = 4.08			
5 X Rated			
Group A	20.73	68.80	92.75
Group B	182751.72	183759.54	24.834
Group C	1146.24	125.44	15.77
Table Value: $F_{.95}$ (1, 30) = 4.17			
10 X Rated			
Group A	935.82	6429.44	2.14
Group B	21166273.	5550596.2	1450.8489
Group C	42222.66	124484.05	18.01
Table Value: $F_{.95}$ (1, 25) = 4.24			

TABLE VI

SUMMARY
39.2K

F - Ratio	Temp. Cycle Load Life	Burn-In Load Life	Initial Noise Load Life
1 X Rated			
Group A	4.0	4.62	1993750.
Group B	102.6	4.33	15.47
Group C	48.24	7.008	-961841.
Table Value: $F_{.95}(1, 60) = 4.00$			
$2\frac{1}{2}$ X Rated			
Group A	291669.9	69373.8	1.5969
Group B	2872.587	2217.9	1.151
Group C	30917.4	4.863	78540.3
Table Value: $F_{.95}(1, 40) = 4.08$			
5 X Rated			
Group A	2.747	39.96	123.67
Group B	1716.5	560.62	4.196
Group C	959.34	443.88	39.85
Table Value: $F_{.95}(1, 30) = 4.17$			
10 X Rated			
Group A	9614.26	2805.9	2.014
Group B	Unable to Determine		
Group C	Unable to Determine		
Table Value: $F_{.95}(1, 25) = 4.24$			

TABLE VII

resistance change in most cases was not significantly large enough to compare variances. Data comparisons are shown in Tables II, III, IV and V. Significant differences are seen in all cases for each Manufacturing Type with the exception of two cases (i.e. the 100 ohm, 1 X rated power and 39.2K, $2\frac{1}{2}$ X rated power for Type A).

The various temperature stress data were combined for each power stress condition in this comparison.

2.3 Comparison of Each Screen Test with Life Test for Each Manufacturing Type

The variance of data for each screen test performed was compared with the variance of load life data for each Manufacturing Type and each power stress condition. The various temperature stress conditions were combined to provide adequate sample sizes for comparison. The S.T.O.L. test data again was omitted for reasons given in Paragraph 2.2. The data summary is presented in Tables VI and VII.

2.4 Phase III Tests

Screen testing was performed on one-half of the resistor units to be tested in the Phase III Life Tests. The matrix conditions for the Phase III Life Tests were selected as shown in Table VIII.

Matrix I	- 125°C	@ 1	X Rated Power
Matrix II	- 70°C	@ 2.5	X Rated Power
Matrix III	- 125°C	@ 2.5	X Rated Power
Matrix IV	- 150°C	@ 10	X Rated Power

TABLE VIII

An arbitrary selection of 1% resistance change in the Life Test is expected to produce no failures in Matrix I, an intermediate number of failures in Matrix II and Matrix III, and 100% failures in Matrix IV. Matrix I is then to be considered the base condition.

Phase III life tests were initiated and 40 units were damaged due to an accidental voltage overload. These units were replaced from the standby units. Serial numbers of the parts damaged and their replacements are as listed in Table IX.

Mfg. Type	Damaged Units	Replacements
A	030341 to 030380	030502 to 030541
B	034341 to 034360	034501 to 034520
C	036341 to 036360	036521 to 036540

TABLE IX

3.0 ANALYSIS

Application of the methods of analysis of variances as described in Reference (1) of The First Quarterly Progress Report indicates the differences in the Life Test results of "screened" and "unscreened" resistors as was shown in Table I. It is then to be determined if the effects of "screening" are beneficial or detrimental. Also to be determined is which screen test or tests yield data which will closely correlate to the Life Test results; thereby predicting in advance the operating life characteristics of a resistor or lot of resistors.

3.1 Effects of Screen Tests

Examination of Table X indicates that approximately 1/2 of the test groups indicate a smaller mean resistance change and, or a smaller deviation for the screened groups. Approximately 25% of the groups tested indicate both a smaller mean resistance change and deviation for the screened groups.

It should be pointed out here that the Life Tests for the screened groups included those units which displayed excessive resistance changes during Screen Testing.

It is felt at this point that removal of the non-conformists after Screen Testing and prior to Life Testing would show a definite superiority in both the mean resistance change and deviation for the screened units over the unscreened units. This is to be examined in closer detail in a future report.

3.2 Correlation of the Various Screen Tests with Life Test

Examination of Tables VI and VII does not indicate strict correlation for any particular Screen Test and Life Test for

EFFECTS OF SCREEN TESTS

100 OHM

	X1		X2½		X5		X10	
	Mean	Dev.	Mean	Dev.	Mean	Dev.	Mean	Dev.
25°C:								
Screened	-.072	.010	-.08	.029	-.017	.050	.14	.153
Unscreened	-.064	.022	-.065	.024	-.046	.028	.12	.086
70°C:								
Screened	-.088	.030	-.227	.026	-.042	.044	.34	.221
Unscreened	-.091	.036	-.094	.025	.041	.086	.44	.304
125°C:								
Screened	-.023	.015	.043	.137	.045	.028	2660	48.8
Unscreened	-.026	.035	.004	.064	.085	.027	4240	55.0
150°C:								
Screened	.268	.607	1.53	2.93	7.10	7.39	3520	51.7
Unscreened	.386	.723	1.42	2.77	4.75	1.82	2450	45.6

39.2K

	X1		X2½		X5		X10	
	Mean	Dev.	Mean	Dev.	Mean	Dev.	Mean	Dev.
25°C:								
Screened	-.037	.020	-.496	.040	.297	.614	.157	.057
Unscreened	-.023	.015	-.270	.070	.125	.196	.157	.081
70°C:								
Screened	-.077	.043	-.044	.125	.655	.232	--	--
Unscreened	.093	.025	.095	.025	-.068	.111	--	--
125°C:								
Screened	-.005	.034	.331	.290	10.1	1.99	--	--
Unscreened	-.037	.073	.326	.320	1.60	1.67	--	--
150°C:								
Screened	.182	.160	2.33	1.06	26.2	3.44	--	--
Unscreened	.213	.206	5.00	1.65	28.1	3.90	--	--

TABLE X

all manufacturing types. Examination of additional data collected from the 4000-hr. extended Life Test is expected to provide additional information, especially in the low and medium stress levels. Other work in this area has indicated a direct correlation between the 100-hr. Burn-in Test and extended Life Test.

3.3 Recommendations

It is recommended that the Contractor proceed with testing and data analysis as scheduled.